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DISINTEGRATION OF PORTLAND CEMENT BRIQUETTES

BY OIL AND EXPERIMENTS TO PREVENT IT

by

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A Thesis Submitted for the Degree

of

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About two years ago, (Jan.1903) it was accidentally discovered in the cement testing laboratory of the C M & St P Railway, Mr. C F Loweth, Engineer and Superintendent of Bridges and Buildings, that oil disintegrated Portland cement. Briefly the circumstances were as follows:- A two year old neat Portland cement briquette which had been in use in the laboratory as a paper weight was laid aside where it was exposed to occasional drippings of signal oil. In ten months the briquette began to disintegrate. Photograph No. 1 shows the effect after being exposed for that period.

Up to this time, (two years ago) there was considerable difference of opinion in regard to the effect of oil on concrete. In fact, there is today. Many consider it entirely harmless, and to prove their assertions call attention to machinery foundations in use for many years, which, though exposed to waste oil, are perfectly sound. On the other hand, there are many who believe the contrary to be true, and tell about concrete disintegrating where oil appeared to be the sole cause. The laboratory test above referred to proves clearly that oil must have a powerful effect on concrete mortar, to disintegrate a two year old briquette. It therefore seemed of great value to make further investigations, because concrete is used

extensively in places where waste oil cannot be avoided, such as engine and machine foundations, turn table and round house pits, draw bridge piers and abutments, floors in oil storage houses, etc. The result of the discovery referred to indicates that concrete when used where oil can reach it may disintegrate in time, and thus result seriously.

Consequently, an examination was made of a great many concrete structures on which more or less oil was found. There were a limited number of instances where the concrete was possibly affected by oil, but in these cases it was very old, and the character of the original material and the workmanship was questionable. On the other hand, none which was built in late years, and known to be of good quality, was affected to any perceptible degree if at all. One case which particularly attracted our attention, was the concrete floor of an oil house in which lubricating and lighting oils had been stored for six years without any apparent effect. The penetration of the oil was slight, perhaps not to exceed one sixteenth of an inch; moreover, the saturated portion seemed to be as sound as the rest. There were other instances where the oil had penetrated deeper, as for example, in the pits of a round house, the oil had gone in from one quarter to one half of an inch, while in other respects, the concrete seemed perfectly normal. These pits however, had been in

use only about a year when investigated. It will thus be seen that while the investigation seemed favorable for the structures examined, our observations could not be taken as conclusive for all concrete structures.

We then decided upon laboratory experiments in which the test pieces consisted of Portland cement briquettes made of neat cement, 1:3 of sand and 1:3 of limestone screenings that were allowed to age four days in the laboratory air, and were then subjected to applications of signal oil. (See "First Series" "Table I") At first, small quantities of oil (enough to saturate) were applied daily and later the applications were less frequent, depending upon the amount the briquette absorbed. Cracks developed in the sand and limestone briquettes first, in which they appeared at the age of two and one half months, (See Photograph No. 2) while the neat briquettes showed similar results in five months. A sand briquette of the same series is shown in photograph No. 3, at the age of six months when larger cracks had developed. Photograph No. 4 is the same briquette after crushing in the hand, thus showing the disintegration to be complete. All briquettes eventually disintegrated.

After obtaining these results, a still more extensive series of tests was started. The "first series" was confined to one oil (signal) and a single cement, while the "Second Series", (See Table I) included a characteristic oil or fat from each of the five different groups

which are most common, and one each of the three varieties of cement, classed according to the raw material from which they are manufactured. The oils and fats used were as follows:-

			Vegetable Oil	
Class -	Animal Fat	Animal Oil	Semi-drying	Drying
Kind -	Ext. of Lard	Whale	Castor	Bo. Linseed
		Mineral		
		Crude Petroleum		

In addition to these, signal oil, (which is a mixture of animal fat and mineral oil) was also used because it served for a comparison with the previous tests. In choosing the cement, a well known brand of Portland was selected from those manufactured from stone and clay, another from marl and clay, and the third from slag and stone.

Neat and 1:3 sand briquettes from all these varieties of cement were then made, and treated each with the six different kinds of oils and fats. A total of about 800 briquettes were required to cover the entire series of tests, (including those made for comparison but not treated with oil). All briquettes were left in the laboratory air seven days before starting the oil treatment which was similar to that used in the former test. The oil applications were continued until the tests ended, or nine months after they were started. Tensile tests were obtained of the oil treated briquettes and also (for comparison) of two similar sets without oil, one of which was kept in water, and the other in laboratory air. The bri-

briquettes were broken at 28 days, 3, 6, and 9 months, except when disintegration prevented.

In regard to the results; I will not take the space to reproduce the tensile tests, however, all other information regarding them is shown in Series II of Table I. The greatest effect was caused by animal fat or extract of lard oil which disintegrated most of the neat and sand briquettes in from one half to two and one half months. However, it failed to destroy some, even at the end of nine months, when the tests were discontinued. As a rule the neat briquettes were affected first, which was contrary to what was noticed in the first series of tests. Photographs 5, 6 and 7 show the results of the lard oil treatment on the nine months old briquettes of all three varieties of cement. It will be seen that the stone clay class was disintegrated the least and the slag-stone the most. The above order of disintegration however, was not followed in all cases. In this connection I also wish to say that the raw materials out of which a cement is made did not seem to govern the effect of the oil on the cement; instead the peculiar characteristics of each cement apparently regulated that. Next in effect was signal oil, a mixture of animal fat and mineral oil which acted only slightly different from the extract of lard. Following this was the whale and castor oils which caused considerably less disintegration than either of the two before mentioned. Only a small percentage of the briquettes treated with these

oils were affected in outward appearance up to the end of the test. The two remaining oils, petroleum and boiled linseed, did not disintegrate any of the briquettes up to nine months. Petroleum however, penetrated, affected the strength somewhat, and possibly would have eventually destroyed it, while boiled linseed formed a coating without penetrating. Of the five classes, boiled linseed was the only one that apparently did not effect the strength of the briquettes; no doubt due to oxidation which prevented it from soaking in. Had it not dried before penetrating, it possibly would have disintegrated the briquette to the same extent as castor, the other vegetable oil used.

We have now seen the effect of oil on the weaker briquettes. I say weaker, because it will be remembered that the first series of tests which consisted of only a few, were treated with oil after four days old, and the second longer series after seven days. Also that these were not regularly cured briquettes, but exposed to the laboratory air instead of water after making, which method was used to allow the briquettes to dry so they would more readily absorb the oil. Therefore, their age when the oil was first applied, and the method of curing naturally made these briquettes more susceptible to oil than if they were older and cured in water, which was intended in order to make the effect of the oil treatment more pronounced. To supplement the tests on these weaker briquettes, experiments were made with older ones which were cured according to the regular laboratory practice. Some

of these tests were as follows: a neat, a 1:1 a 1:2 and a 1:3 sand briquette, all of which were two years old, were dried at the stove for twenty days, and then treated with signal oil. Though it has been practically two years since the oil was first applied, with one exception they show no signs of disintegration, and this was only noticeable since this paper was started. In addition to this, the above briquettes were made of silica cement (instead of the regular Portland) consisting of equal portions of sand and Portland Cement (ground together to a fineness that passed through a No. 200 sieve) which therefore were weaker than the standard Portland cement briquettes of the same mixture. The one that failed was the weakest of the four, being a mixture of one of silica cement to three of sand. Another test consisted of a neat and a 1:3 sand briquette, which were taken from the vat at the age of one year, and treated with signal oil, both of which appear to be perfectly sound though soaked in oil for practically one year. Still another specimen was a 28 day neat briquette which was dried by exposing to the laboratory air for three months after which signal oil was applied. At the age of eight months the briquette was disintegrated. Eight one year old briquettes were also included in this series, which are still sound. However, they were immersed in oil only nine months, and moreover were otherwise treated to prevent the action of the oil. (These I will speak of later). In connection with this series of older briquettes, we are experimenting with a piece of concrete from the oil house

floor before mentioned, which, though in use for six years, was not perceptibly affected. This piece of concrete has now been immersed in oil for ten months, and is still sound. It will thus be seen that only two briquettes out of the long time series of fifteen, failed, both of which were the weakest in the lot. One of these was 28 days old when taken from the vat, which (if an average briquette) would have broken at from three-quarters to seven-eighths of its ultimate strength.

The other while set for two years in water, was a comparatively lean mixture, being made of one part of silica cement and three parts sand which would have broken at from three-quarters to seven-eighths of the strength of a 1:3 regular Portland. The specimen of concrete and the rest of the briquettes show no signs of failure. However, the oil has penetrated throughout, and also possibly weakened them.

Thus far, our investigation may be summarized briefly as follows: At the outset we failed to find a specimen of concrete that we felt was positively disintegrated by oil, though we not infrequently heard of it, as for example, the pedestal under a cream separator, which case seemed possible because it is an instance of almost continued application of animal fat, apparently the worst condition that could exist. On the other hand, plenty of concrete was found that oil had penetrated but not disintegrated. Further, our tests of comparatively new briquettes, which were weakened by exposure to air, showed that with one exception, they were or affected by disintegrated by all classes of oils and fats. These

and fats when arranged according to their effect (as far as our experiments indicate) are as follows: Animal Fat, Animal Oil, Vegetable Oil and Mineral Oil. The exception to the above was the drying vegetable oil, which, unlike the semi-drying, oxidized before penetrating. It was apparently the only one which had no effect. In these tests animal fat had a much greater effect than the oils. Only a small percentage of the briquettes were disintegrated at the end of the tests (or nine months after the first application) by the oils which contained no fat. (I wish to add here however, that our tests are not extensive enough to say whether the above arrangement of the fats and oils according to their effect on briquettes, would hold true if other oils had been experimented with because their chemical compositions vary so much). And last, out of the fifteen old briquettes which were seasoned according to the laboratory practice, only two have been outwardly affected, though treated from nine months to two years, and these two were the weakest, as before pointed out. The briquettes which remained unaffected were cured from one to two years in water before treating. Though only two of the fifteen have been destroyed by oil, all have been penetrated, and also possibly may fail in time.

With all this in view, we are still uncertain as to the possible final effect of fats and oils on concrete structures.

On the following points however, we are reasonably sure; First, most oils penetrate concrete mortar, which makes them objectionable. Second, concrete is more liable to be

disintegrated when saturated with oils and fats if not thoroughly set. Third, a good quality of concrete is less susceptible to the effect of oil than a poor, such as a porous, lean, frosted, poorly mixed or improperly seasoned concrete. Fourth, ordinary concrete work is rarely subjected to continued large doses of oils but more often is only occasionally spattered. Disintegration under the latter conditions, seems remote, especially in the case of first class, well seasoned concrete. (The concrete floor above mentioned is an excellent example. The oil spattered on it perhaps was oxidized or absorbed by the dust, and instead of penetrating, helped to protect it). Last, even though subjected to the equivalent of continued saturation, the disintegration would be long drawn out if the concrete were properly made and well set.

Our conclusions may eventually be altered, though it must necessarily be a long time before definite results will be obtained from the tests under way. In the meantime, more experiments will be started, especially on the poor quality of concretes, and also tensile tests on well seasoned briquettes.

Table I, shows the effect of oils on Portland cement briquettes which I have just finished discussing. A study of it will perhaps reveal more than has been said. It does not include the tensile tests nor the untreated briquettes which were made for comparison.

I also wish to call your attention to the more complete classification of Fats and Oils shown elsewhere, in which

the sub-divisions are made from a physical and chemical standpoint. In the latter respect however, the classification is not as good as the former because the chemical compositions of oils differ largely even of the same sub-division. While only the more common primary fats and oils are given, it can be seen that a wide range of experiments is desirable to cover the entire field, which is all the more necessary because of the chemical differences before spoken of.

We have now seen the effect of oil; next we are naturally interested to know what will prevent it. Under unfavorable conditions, it seems very desirable to use a wash for oil spattered concrete that will prevent oils from penetrating. Moreover, it is possible that concrete seasoned according to ordinary practice will not resist oil as well as the water cured briquettes. Most of all to be protected are oil-spattered reinforced structures, where the strength depends entirely upon the quality of the concrete. It would then be a great relief if some simple wash could be applied to protect it from oils.

While experimenting with the effect of oils, we made several attempts to discover something that would answer the purpose. Our attention was first attracted to Linseed Oil which you remember, did not penetrate, but formed a coating on the outside of the briquette that apparently protected it. However, after two months application of signal oil, the linseed oil was penetrated, and later the briquette was disinte-

grated. Other oils were slower in their action on linseed oil.

Another experiment was made with alternate washes of a 5% solution of alum and a 7% solution of castile soap (known as Sylvester's process of making concrete impervious to water"), which combination forms an insoluble precipitate that fills the voids. Five washes of each were applied alternately but this coating failed to prevent the oil from attacking the mortar.

These same solutions were also tried in a different way, by making the briquettes with them instead of water. One solution was first thoroughly mixed with the cement and the other solution added just before moulding into a briquette. When treated with oil, these showed up inferior to the other method. (Moreover the briquettes broke about 20% below the untreated, which weakening is contrary to what has been claimed for it). Photograph No. 8 shows the briquettes which were made according to this process, and after fourteen days old, treated for six months, with extract of lard oil. Photograph No. 9 shows briquettes of the same series which were made in the regular way. Photographs 10 and 11 are similar except that signal oil was used in place of extract of lard oil.

We next experimented with paraffine, because there are few things that attack it, including all acids and alkalies. I believe I am right in also saying that the obelisk

in Central Park, New York, ~~was~~ was treated with it to prevent weathering. Part of the briquettes were coated with it on the outside by dipping them in hot paraffine, and other briquettes were heated and held in hot paraffine until they became penetrated an eighth of an inch. Neither of these experiments apparently prolonged the time before disintegration by oils. The results were a great disappointment.

Sodium silicate, or what is known as water glass, was the last tried. It is a fire-proof oil or varnish, sometimes used to prevent stone from weathering. This coating dissolved in 20 days and one of the briquettes disintegrated although the oil was applied for only about one and one half months.

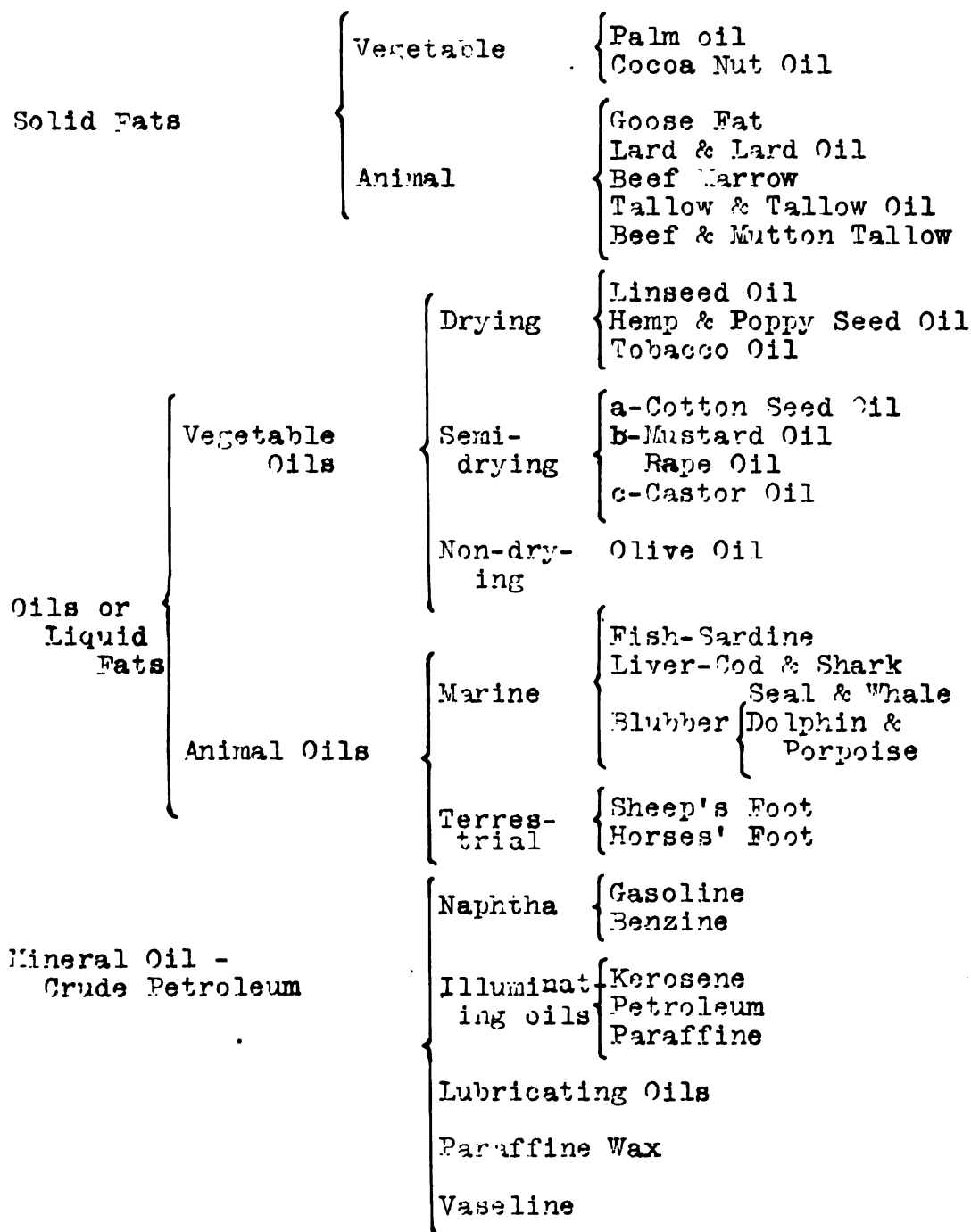
Table II covers the tests on the briquettes which were treated to preserve them from the effects of oil. A study of it will perhaps reveal more than has been pointed out in the paper.

The difficulty experienced in finding a cheap wash that will absolutely protect concrete from oil is apparent. Something is needed that will penetrate into the concrete to allow for wear, and most of all be inexpensive. This paper ought to bring the matter to the attention of engineers and concrete users, and start further investigations along these same lines, or at least bring out suggestions that can be tried in established laboratories. Let us hope that it will soon be unnecessary to use brick facing and stone caps

for concrete structures exposed to oil, or in the absence of these feel uneasy about the final character of the concrete. Moreover, we do not want to limit the use of reinforced concrete to those places where there is no oil.

In closing I wish to say that we greatly appreciate the work of our cement tester, Mr. Geo. J Griesenauer, in furthering these investigations.

CLASSIFICATION OF FATS AND OILS IN WHICH ONLY THE MORE COMMON
PRIMARY FATS AND OILS ARE GIVEN





No. 1
Disintegrated by Signal Oil
Three years old
Neat Portland cement
Oil applied for 10 months
Previously used for
paper weight.



No. 2
Disintegrated by Signal Oil
Two and one half months old
Portland Cement briquettes
1:3 Sand & 1:3 Limestone screen
Four days old in air before
oil was applied



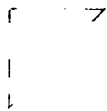
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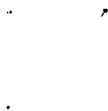
No. 3
 Disintegrated by Signal Oil
 Six months old
 Portland cement and sand 1:3
 Four days old in
 air when oil was applied.



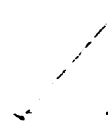
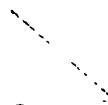
No. 4
 Disintegrated by Signal Oil
 Crumbled in hand
 Six months old
 Port. cement and sand 1:3
 Four days old in air
 When oil was applied



3



4





No. 5
 Disintegrated by Ext.of Lard Oil
 Nine months old
 Portland Cement (Stone & Clay)
 Neat and sand briquettes
 Seven days old in air before
 oil was applied
 Began failing in 2-1/2 months.



No. 6
 Disintegrated by Ext.of Lard Oil
 Nine months old
 Port.cement (Marl & Clay)
 Neat and sand briquettes
 Seven days old in air before
 oil was applied
 Began failing in two months

7

4

5

2

3

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6

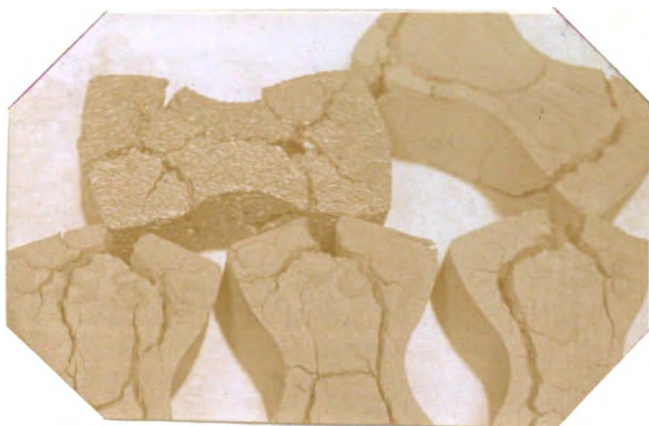
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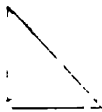
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No. 7
 Disintegrated by Ext. of Lard Oil
 Nine months old
 Portland cement (Slag & stone)
 Neat and sand briquettes
 Seven days in air before oil
 was applied
 Began failing in one month



No. 8
 Six months old briquettes (treated)
 Made up with alum (5%) soap (7%)
 solution instead of water
 Portland cement (Marl & Clay)
 Neat and sand briquettes
 Seven days in damp box 7 days in air
 Ext. of Lard oil then applied
 Began failing in 40 days





No. 9

Six months old untreated briq.
(for comparison to #8)
Portland cement (Marl & Clay)
Neat and sand briquettes
Seven days in damp box 7 days in air
Ext. of Lard Oil then applied
Began failing in 15 to 20 days



No. 10

Six months old treated briquette
Made up with alum (5%) soap (7%)
solution instead of water
Portland cement (Marl & Clay)
Neat and sand briquettes
Seven days in damp box 7 days in air
Signal oil then applied
Began failing in from 3 to 4 months



No. 11

Six months old untreated briq.
(for comparison with #10)
Portland cement (Marl & Clay)
Neat and sand briquettes
Seven days in damp box 7 days in air
Signal oil then applied
Began failing in 1-1/2 months

16

11

Approved, for the committee on the thesis by the Faculty of the College of Science and Engineering.

W. D. Taylor

Approved, for the committee appointed to examine this
thesis by the Faculty of the College of Mechanics
and Engineering.

M. D. Taylor Chairman.

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